CLAIMS

We claim:

1. A chemical reactor comprising:

at least one reaction chamber comprising at least one porous catalyst material and at least one open area wherein each of said at least one reaction chamber has an internal volume defined by reaction chamber walls;

wherein said internal volume has dimensions of chamber height, chamber width and chamber length;

wherein said at least one reaction chamber comprises a chamber height or chamber width that is about 2 mm or less;

wherein, at a point wherein said chamber height or chamber width is about 2 mm or less, said chamber height and said chamber width define a cross-sectional area;

said cross-sectional area comprising a porous catalyst material and an open area, wherein said porous catalyst material occupies 5% to 95% of the cross-sectional area and wherein said open area occupies 5% to 95% of the cross-sectional area;

wherein said open area in said cross-sectional area occupies a contiguous area of 5×10^{-8} to 1×10^{-2} m^2 and wherein said porous catalyst material has a pore volume of 5 to 98 % and more than 20% of the pore volume comprises pores having sizes of from 0.1 to 300 microns.

2. The reactor of claim 1 comprising a bulk flow channel that is contiguous over the length of the reaction chamber.

3. The reactor of claim 2 wherein the bulk flow channel is essentially straight.

4. The reactor of claim 2 comprising 5 to 1000 bulk flow channels.

5. The reactor of claim 1 wherein said porous catalyst material comprises a core of a relatively large pore first material and a coating of a relatively small pore second material disposed over at least a portion of said first material.

6. The reactor of claim 1 comprising at least 5 reaction chambers.

7. The reactor of claim 1 comprising multiple reaction chambers and at least one mixing chamber disposed such that gases from at least two reaction chambers can mix in the at least one mixing chamber.

8. The reactor of claim 2 comprising offsetting porous dividers.

9. The reactor of claim 2 further comprising a microchannel heat exchanger in thermal contact with said reaction chamber.

10. The reactor of claim 2 wherein said porous catalyst material is a discrete unit that can be inserted into or removed from the reaction chamber.

11. The reactor of claim 2 further comprising a gas compartment and a flow distribution layer wherein the flow distribution layer is disposed between the gas compartment and the reaction chamber such that gas can flow from the gas compartment through the flow distribution layer to the reaction chamber.

12. The reactor of claim 2 further comprising a gas compartment; wherein a porous catalyst material is disposed between said gas compartment and an open area of said reaction chamber.

13. A chemical reactor comprising:

at least one reaction chamber comprising catalyst rods, plates or baffles having a length to thickness ratio of at least 10, and wherein each of said at least one reaction chamber has an internal volume defined by reaction chamber walls;

wherein said internal volume has dimensions of chamber height, chamber width and chamber length;

wherein said at least one reaction chamber comprises a chamber height or chamber width that is about 2 mm or less; and

wherein said catalyst rods, plates or baffles are disposed in said reaction chamber such that the pressure drop across the reaction chamber is less than 20% of the total system inlet pressure.

14. The reactor of claim 13 wherein said at least one reaction chamber comprises fibers or baffles and said fibers or baffles comprise a porous catalyst material.

15. A chemical reactor comprising:

at least one reaction chamber comprising at least three layers:

a first layer comprising a first porous catalyst material;

a second layer comprising a heat exchanger and at least one fluid flow path through said second layer, said second layer disposed in the reaction chamber such that fluid passing through the first layer can pass through said at least one fluid flow path, and

a third layer comprising a second porous catalyst material said third layer disposed in the reaction chamber such that fluid passing through the second layer can pass into said second porous catalyst material;

wherein said first layer has contiguous channels having dimensions of channel height, channel width and channel length;

wherein said at least one of said contiguous channel comprises a channel height or channel width that is 0.1 micrometers to about 2 mm;

wherein at least part of said at least one of said contiguous channels comprises said first porous catalyst material; and

wherein said first porous catalyst material has a pore volume of 5 to 98 % and more than 20% of the pore volume comprises pores having sizes of from 0.1 to 300 microns.

16. The reactor of claim 15 wherein said heat exchanger comprises a microchannel heat exchanger.

17. The reactor of claim 16 wherein said at least one of said contiguous channels comprises a channel height or channel width that is 0.3 micrometers to 2 mm; and wherein said third layer layer has contiguous channels having dimensions of channel height, channel width and channel length, wherein at least one of these contiguous channels comprises a channel height or channel width that is 0.3 micrometers to 2 mm.

18. The reactor of claim 17 wherein said at least one fluid flow path comprises a microchannel.

19. The reactor of claim 16 wherein said first layer has an inlet and said third layer has an outlet and further comprising a conduit connecting said outlet to said inlet.

20. The reactor of claim 19 wherein said conduit contains a separating agent.

21. The reactor of claim 17 wherein the porous catalyst material in said first layer comprises a metal foam or felt.

22. A method of hydrocarbon steam reforming comprising:

passing a reactant stream comprising steam and hydrocarbon into at least one reaction chamber;

said reaction chamber having an internal volume wherein said internal volume has dimensions of chamber height, chamber width and chamber length;

wherein said at least one reaction chamber comprises a chamber height or chamber width that is 2 mm or less;

wherein said at least one reaction chamber has a beginning and an end and wherein said chamber length is the distance from the beginning to the end of the reaction chamber;

wherein said reactant stream entering the beginning of the reaction chamber is converted to a product stream exiting the reaction chamber;

said product stream comprising hydrogen, carbon dioxide and carbon monoxide;

wherein at least 70% of said equilibrium conversion of the hydrocarbon entering the beginning of said at least one reaction chamber is converted to hydrogen, carbon monoxide and/or carbon dioxide; and

wherein said hydrocarbon has a contact time of less than 300 milliseconds.

23. The method of claim 22 wherein the reaction chamber comprises a porous catalyst material and a bulk flow channel.

24. The method of claim 23 wherein the bulk flow channel is contiguous from the beginning to the end of the reaction chamber.

25. The method of claim 23 wherein there a multiple bulk flow channels within said reaction chamber.

26. The method of claim 23 wherein there is a pressure drop from the beginning to the end of the reaction chamber that is less than 20%.

27. The method of claim 23

wherein the hydrocarbon comprises of methane;

wherein at least 90% of said equilibrium conversion of the methane entering the beginning of said at least one reaction chamber is converted to hydrogen, carbon monoxide and/or carbon dioxide; and

wherein the methane has a contact time of less than 30 milliseconds.

28. The method of claim 27 wherein the reaction chamber comprises sides and at least two sides of said reaction chamber have a porous catalyst material.

29. The method of claim 27 wherein the porous catalyst material has a pore volume of 5 to 95 % and more than 20% of the pore volume comprises pores having sizes of from 0.3 to 200 microns.

30. The method of claim 23 futher comprising the step of adding heat to the reaction chamber from an adjacent microchannel heat exchanger.

31. A method of conducting a chemical reaction in a chemical reactor comprising:

passing a gaseous reactant into a first compartment of a reaction chamber;

wherein said reaction chamber comprises a porous catalyst material, a first compartment and a second compartment;

wherein said first compartment has an internal volume wherein said internal volume has dimensions of compartment height, compartment width and compartment length;

wherein said first compartment comprises a compartment height or chamber compartment that is about 2 mm or less;

wherein said porous catalyst material is disposed between said first compartment and said second compartment;

wherein said gaseous reactant reacts within said porous catalyst material to form at least one product; and

wherein said first compartment and said second compartment comprise open spaces that permit bulk flow of a gas.

32. The method of claim 31 wherein said at least one product passes into the second compartment.

33. The method of claim 31 further comprising passing a second gaseous reactant into the second compartment, wherein the gaseous reactant from the second compartment travels into the porous catalyst material and reacts with the gaseous reactant from the first compartment.

34. A method of conducting a chemical reaction in a chemical reactor comprising:

passing a gaseous reactant into a first and/or second compartment;

wherein a partition is disposed between the first compartment and the second compartment;

wherein said partition comprises a fluid distribution layer or a separating agent;

wherein said first compartment has an internal volume wherein said internal volume has dimensions of compartment height, compartment width and compartment length;

wherein said first compartment comprises a compartment height or compartment width that is about 2 mm or less;

wherein said first compartment comprises a porous catalyst material;

wherein a gas travels through said partition; and

wherein said first compartment comprises at least one open space that permits bulk flow of a gas.

35. The method of claim 34 wherein said second compartment comprises at least one open space that permits bulk flow of a gas, and said partition comprises a flow distribution layer;

wherein said gaseous reactant convectively travels through the flow distribution layer from the first to the second compartment;

wherein said gaseous reactant, after traveling through said flow distribution sheet, reacts in a porous catalyst material contained within the second compartment.

36. The method of claim 34 wherein said second compartment comprises at least one open space that permits bulk flow of a gas, and said partition comprises a separating agent selected from the group consisting of a membrane and a sorbent.

37. The method of claim 34 wherein said chemical reactor comprises multiple reaction chambers arranged in parallel or in series; and

comprising passing a gaseous reactant into the first compartment of multiple reaction chambers.

38. The method of claim 36 wherein said separating agent comprises a palladium membrane, and wherein said method comprises continually removing hydrogen through the palladium membrane.

39. A method of conducting a chemical reaction comprising:

passing a gaseous reactant into a bulk flow path of a reaction chamber;

said reaction chamber having an internal volume wherein said internal volume has dimensions of chamber height, chamber width and chamber length;

wherein said at least one reaction chamber comprises a chamber height or chamber width that is about 2 mm or less;

wherein a porous catalyst material is disposed within said internal volume, wherein said porous catalyst material has a porous internal structure such that the gaseous reactant can diffuse molecularly within the material;

wherein the gaseous reactant reacts in the porous catalyst material to form at least one product; and

wherein said bulk flow path is contiguous throughout said chamber length.

40. The method of claim 39 wherein the contact time of the gaseous reactant in the reaction chamber is less than 100 milliseconds.